PARTICIPATION INDEX: AN IMPROVEMENT TO THE MEASURE OF TRANSPORT RELATED SOCIAL EXCLUSION?

Mr. Md. Kamruzzaman
PhD Student, Built Environment Research Institute (BERI)
University of Ulster

Prof. Julian Hine
Professor, Built Environment Research Institute (BERI)
School of the Built Environment, University of Ulster

Dr. Banihan Gunay
Lecturer, Built Environment Research Institute (BERI)
School of the Built Environment, University of Ulster

Dr. Neale Blair
Lecturer, Built Environment Research Institute (BERI)
School of the Built Environment, University of Ulster

Abstract

Although transport related social exclusion has been identified through zonal accessibility measures in the recent past, the debate has shifted from zonal to individual level measures. One way to identify disadvantaged individuals is to measure their size of participation in society (activity spaces). After reviewing existing literature, this paper has found two approaches to measure the activity spaces. One approach is based on the time-geographic potential path area (PPA) concept. The size of the PPA has largely been used as an indicator to the size of potential activity spaces and consequently individual accessibility. The limitations of the PPA concept have been identified in this paper and it is argued cannot be applied as a measure of social exclusion. The other approach is based on individuals' actual travel-activity participation called actual activity spaces. The size of actual activity spaces possesses a good potential measure of social exclusion. However, the indicators to measure the size of actual activity spaces are multidimensional representing the different aspects of social exclusion. The development of a unified approach has therefore been found to be important. This paper has developed a participation index (PI) using the different dimensions of actual activity spaces encountered. A framework has also been developed to operationalise the concept in GIS. The framework, on the one hand, will visualize individuals' actual travel behaviour in real geographic space; on the other hand, it will calculate the size of their participation in society.

1. Introduction

Social exclusion is now an integral part of many policy domains in the UK (DfT, 2006; Preston and Rajé, 2007). Despite differences in opinion regarding its interpretation, a common agreement found in the literature is that social exclusion is a multidimensional process (Lyons, 2003; Rajé, 2003; Miller, 2006). The dimensions are: economic, societal, social networks, organised political, personal political, personal, living space, temporal, and mobility (see, Kenyon et al., 2002). Although Burchardt et al. (2002) have mentioned a scarcity of empirical treatments of social exclusion, two broad approaches can be distinguished in the literature. One approach is based on the quantification of the phenomena using the indicators of the processes leading to social exclusion (see, Atkinson, 1998). The other has quantified the phenomena using indicators of its outcome (see, Burchardt et al., 1999; 2002). A variety of definition of social exclusion exists in the literature (see, Rajé, 2003; 2007). Despite this variety, a common aspect found in all these definitions is that societal processes prevent people from 'participating' in activities. As a result, participation has been considered as the outcome of social exclusion and the later approach has quantified different dimensions of participation.

From an operational perspective, a major difference between the approaches is their unit of analysis. The former approach has focused at some level of geographic aggregation whereas individual is the subject for evaluation in the later approach (DfT, 2006; Miller, 2006). It is worth to mention that none of the above approaches are without criticism. Lyons (2003) has indicated that treating the excluded in isolation is like treating the symptoms than the illness. Unlike Lyons, Miller (2006) has mentioned that exclusion covers all aspects of an individual's life; only some of which occur at a particular place. An area having service facilities close by does not necessarily mean that all people living in that area would be able to participate in those facilities (Church et al., 2000). Since participation is the key, many researchers have focused on the mobility dimension of social exclusion. Hine and Mitchell (2003) have mentioned that the mobility dimension is central among the dimensions because participation in activities depends on access to facilities. This has made a strong link between transport and social exclusion; and often referred as transport related social exclusion. Preston and Rajé (2007) have mentioned that social exclusion is not due to lack of social opportunities to participate but a lack of access to those opportunities. Therefore, access has been considered as an outcome caused by mobility (Kenyon et al., 2002).

Transport related social exclusion also has been evaluated using the both approaches. Process related indicators (e.g. distance from bus stops) have been used to evaluate the process largely focusing on special groups (e.g. elderly, disabled) whereas different zonal accessibility measures (e.g. isochrones, gravity) have been used to evaluate the outcome (Church et al., 2000)[1]. Disaggregation of these measures is a growing interest in this field (Hine and Grieco, 2003; Preston and Rajé, 2007). DfT (2006) has indicated that disaggregation should be at the socio-economic, spatial, and temporal level to be able to identify the differential impacts of transport policies. Being a key indicator of social exclusion, participation should be explicitly measured both by its nature and its magnitude since the presence of either adequate mobility tools or accessible opportunities does not necessarily ensure participation (Burchardt et al., 2002; DfT, 2006). Burchardt et al. (2002) have mentioned that evaluation of the nature of participation is important because lack of participation in any type of activity is sufficient for social exclusion[2]. By magnitude, Burchardt et al. (2002) have meant temporal extent of participation. They have also found that exclusion on a particular type of activity has much stronger association over time than the associations between different types of activities at a single point in time.

Based on above discussion, adoption of the outcome oriented approach proposed by Burchardt et al. (1999; 2002) is advantageous for two reasons. Firstly, it evaluates different aspects of participation; and secondly, it focuses on individuals. However, traditional accessibility based measures need to be readjusted to adopt the outcome oriented approach required to measure transport related social exclusion. Accessibility (individual) refers to the ability of an individual to reach the opportunities (Kwan and Weber, 2008). It does not explicitly define whether an individual has participated on those opportunities or not. Therefore, a new modelling technique is required to capture the type, extent, and dynamics of participation to evaluate transport related social exclusion. In this context, activity-oriented theory which is largely used by the travel behaviour researchers can provide useful insight (Lyons, 2003). Miller (2006) has stated that social exclusion can best be understood from the perspective of the individual's dynamic life trajectories operating within a particular socio-spatial context. Individual participates in spaces over time. This means that socially excluded persons are also excluded from certain parts of the environment (Geurs and Wee, 2004). An individual's use of space depends on the socio-economic attributes of the travelers (Schönfelder, 2001). Therefore, personal use of space over time (activity spaces) could be used as an important indicator to the outcome oriented measure of transport related social exclusion (Schönfelder and Axhausen, 2003). Despite intensive application in the travel behaviour research, the application of activity spaces to measure transport related social exclusion is fairly limited.

Using the Mobi*drive* travel data, Schönfelder and Axhausen (2003) have found no significant differences to the extent of activity spaces for those who are usually classified as socially excluded. However, the authors have stated that their results should be viewed with caution due to the fact that their sample was not collected with the intent to analyze socio-demographic differences linked

[1] Church et al. (2000) have referred the former as category approach and the later as spatial approach
[2] Burchardt et al. (2002) have classified activity into consumption, production, political, and social type.

to issues of social exclusion. Miller (2006) has established a theoretical construct to use activity spaces (potential path area, discussed in subsequent section) to the measure of social exclusion without any empirical evidence. McCray and Brais (2007) have recently found that home distance from transit route is an important determinant to the size of activity spaces for low-income women in Quebec city. The above two empirical studies have explored the size of activity spaces for those who have been categorically identified as excluded. No efforts so far has been evident in the literature that has attempted to identify who the excluded are using the activity spaces concept. In this context, the objective of this paper is three fold. First, to explore the concept of activity spaces. Second, to review existing knowledge with regard to the operationalisation of the concept. Third, to operationalise the concept to measure transport related social exclusion in the light of the criteria discussed in this introduction. Section 2 of this paper reviews the concept of activity spaces and its operationalisation. Based on the review, Section 3 will discuss its potential use as a measure of social exclusion. Section 4 discusses the development of an index to measure participation and social exclusion using the activity spaces concept. A framework also has been developed in this section to operationalise the index in *ArcGIS*.

2. Concept of activity spaces

Despite differences in operational definition, 'action space' and 'activity space' have often been used interchangeably in the literature (see, Dijst and Vidaković, 1997; Schönfelder and Axhausen, 2003). Action spaces describe an individual's total interaction with the environment (Golledge and Stimson, 1997). It contains all locations about which an individual is aware of or has some knowledge (Buliung et al., 2008). Action space has also been referred as 'awareness space' (White, 1985). Jakle et al. (1976) have divided the concept of action space into two meaningful components: movement and communication. Golledge and Stimson (1997) have denoted the movement component of an action space as the activity space. Movement has been meant by them as: firstly, movement within and near the home; secondly, movement to and from regular activity locations (e.g. work, shop, social); and thirdly, movement in and around the locations where those activities occur. Therefore, activity spaces are considered as the subset of action spaces in which people have direct physical contact (White, 1985; Golledge and Stimson, 1997; Buliung et al., 2008). On the other hand, communication has been regarded as an indirect mean (e.g. telephone, newspaper etc.) of expanding one's spatial knowledge (Golledge and Stimson, 1997).

Researchers' efforts to conceptualise the movement patterns of individual can be traced back to the mid 1960s. Since then two related themes have been progressed in the literature. One theme, influenced by the work of Wolpert (1965) and Horton and Reynolds (1971), looks for actual or observed movement patterns in space (Buliung et al., 2008). The other theme has progressed based on Hägerstrand's (1970) time-geographic concept; this approach largely seeks to model potential movement pattern of individuals subject to spatio-temporal constraints (Ettema and Timmermans, 1997). Due to data availability at the individual level and the advancement of computational technologies, research on both themes has only intensified since the early 1990s (Kwan, 2004; Buliung et al., 2008). A comprehensive list of research on both themes can be found elsewhere and is not discussed here (see, Buliung and Kanaroglou, 2006a).

2.1. Measures of potential activity spaces

Potential activity spaces refer to the opportunities that are reachable by an individual given his time-geographic constraints (Dijst and Vidaković, 1997). The constraints are: capability constraints, coupling constraints, and authority constraints (Hägerstrand, 1970). Capability constraints are linked to the physical limitations of an individual such as eating or sleeping. Coupling constraints restrict travel by imposing where, when and for what duration individuals have to join other people in space and time. Authority constraints relate to the institutional context, and refer to laws and other regulations which imply that particular activities are only accessible at certain times. As a result, the size of an individual's reachable activities is constrained by time and space. For an individual some activities are fixed in time and space (e.g. office) which are called 'pegs' (Cullen and Godson, 1975; Parkes and Thrift, 1980). Participation in other discretionary activities is dominated by the available time and mobility between two successive pegs (Cullen and Godson, 1975; Weber and Kwan, 2002). The time-space path of an individual traces his/her physical movement in space with respect to time. The space-time extent of the path is called time-space prism which delimits the possible locations for the time-space path. During a day, a person can act within several sets of prisms centred on particular activity location; and aggregation of the prisms form a joint outcome for one day (Parkes and Thrift, 1980). This aggregated prism can be used to measure the size of an individual's potential activity spaces (Yu and Shaw, 2008). The strongest disadvantage of the prism construct is related to its operationalisation (Geurs and Wee, 2004). Lenntorp (1976) has projected the prism onto space for its easy operationalisation. The projected space is called potential path area (PPA) or potential action space (Dijst and Vidaković, 1997).

Dijst and Vidaković (1997) have mentioned that the general form of a PPA is an ellipse; the foci of the ellipse represent the successive two pegs and the length of its major axis is half of the product of travel speed and available travel time. They have also added that the form could be a circle or a line. If the successive two pegs represent same location (e.g. home-shop-home), the form becomes a circle. It would be a line if the available time is spent only for travelling between the pegs. The area delimited by the PPA has been considered reachable by an individual and is considered as potential activity spaces for the individual. Therefore, the area has been used as an indicator for individual accessibility (space-time accessibility). The PPA is a continuous geometric (e.g. ellipse) space. Miller (1991) has mentioned that a large part of the PPA is useless for travel and activity participation in reality because travel occurs along street and activities occur at specific location. Thereby, he has discarded the planar form of the PPA and adopted only those discrete locations where activity could take place (e.g. street, buildings) and operationalise it in GIS.

After Miller (1991), network-based approach has been widely adopted to measure individual accessibility using GIS (see, Kwan, 1998; Kwan and Hong, 1998; Kwan, 1999; Weber and Kwan, 2002; Kim and Kwan, 2003; Kwan and Weber, 2008; Yu and Shaw, 2008). They have calculated PPA over network using the available time for an individual between two successive pegs and his speed of travel. They have aggregated all successive PPA in a day to create a daily potential path area (DPPA). Thus the DPPA represents the size of potential activity spaces of an individual and has been used to assess accessibility for the individual. Using the DPPA construct, five indicators to measure the size of potential activity spaces have been found in the literature (Miller, 1991; Weber and Kwan, 2003; Kwan and Weber, 2008). The first measure (mileage) is the total network distance present within an individual's DPPA. The second measure (opportunities) counts the number of activity locations (opportunity) presents within the DPPA. The third measure (area) adds up the square footage of opportunity parcels within the DPPA. The fourth (weighted area) measure accounts the high rise buildings by multiplying the area of the parcels and the building height. The fifth measure (daytime opportunity measure / timed area) takes into account the authority constrains by excluding all opportunities reachable late at night and early in the morning. Kwan (1999) has calculated individuals' DPPA in Franklin County, Ohio, and found the levels of access to urban opportunities to be significantly lower for women than men. Using similar framework, Miller (2006) has investigated the suitability of the DPPA for addressing issues of social exclusion.

2.2. Measures of actual/observed activity spaces

Direct contacts (activity spaces) shape an individual's territory (Golledge and Stimson, 1997). Researchers in different fields have attempted to capture the spatial properties of the territory in an understandable manner. Different approaches have been evident for the quantification of the spatial properties for different levels of activity spaces. The levels are broadly divided into macro-level and micro-level activity spaces. White (1985) has defined macro-level activity spaces as the direct physical contact between cities by the people rather than individual. He has examined the degree to which the macro-level activity spaces vary in shape, areal extent and compactness to explain the directional bias of interregional migration. He has defined the activity spaces in terms of visitation by respondents from six large metropolitan cities in US to thirty other large metropolitan areas. In his study, shape indicates the areal pattern of visitation; areal extent refers to distance from an origin; whereas compactness defines the degree to which the proportions of visitations over shorter distances varies with visitation over longer distances. To measure the compactness of activity spaces, he has used a gravity model and calibrated it to get the distance decay exponent. The slope of the distance decay curve has been used to measure the compactness.

The concept of micro-level activity spaces has received the most attention to the study of human travel behaviour. Micro-level activity spaces refer to the local area within which the movement of an individual occurs during a specified time. Various approaches have been found in the literature to quantify the spatial properties of the actual activity spaces at this level. Activity locations have been represented spatially by points in these approaches and emphasis has been put to measure the spatial properties of the points. Notably, few methods (e.g. kernel density, ellipses, minimum convex polygon) have been adapted from the spatial ecology literature. Originally, these methods have been used to measure non-human animal 'home range'. Home range is the area traversed by an individual animal for its 'normal' activities (Burt, 1943). In this sense, home range and human activity spaces are conceptually similar. The measures of micro-level activity spaces can broadly be classified into four groups: count, distance, area, and density based measures.

One simple count based indicator to the size of activity spaces is the number of activity sites visited by an individual. Wyllie and Smith (1996) have found a positive correlation between the level of extroversion and the number of activity sites visited by middle adolescents (female aged 13-16 and male aged 14-16). They have also used trip frequencies (total number of trips per person per week) to the activity sites as an indicator to the size of activity spaces and found a positive effect to the level of extroversion. Rollinson (1991) has adapted the definition of everyday geography provided by Seamon (1979, p.16) 'the sum of total a person's first-hand involvements with the geographical world in which he or she typically lives' as a measure of activity spaces. In his study, movement of the elderly tenants living in single-room-occupancy hotels has been documented spatially and counted the number of places visited. He has concluded that the everyday geography of the elderly men and women is highly constrained due to poverty and the barriers imposed by their neighbourhood environment e.g. street crime. Goldhaber and Schnell (2007) have studied the relationship between ethnicity and the level of segregation using the activity spaces concept of everyday life. They have derived a ration of visited activities to the total number of activity locations present in a region for an individual as an index of the size of activity spaces. Despite its usefulness, count based measures exhibit very little about the extent of an individual's activity spaces. Instead researchers have used distances between activities as an indicator to the size of activity space.

Schönfelder (2001) has used total distance travelled by an individual as an indicator for his size of activity spaces. He has found that the amount of travel is influenced by the occupational characteristics of travellers on the one hand. On the other hand, the size also varies over time at the intra-personal level. Unlike Schönfelder (2001), Buliung and Kanaroglou (2006b) have used total daily household kilometres travelled (DHKT) as an indicator to the size of household activity spaces. They have used Euclidean distance between successive activities to measure the DHKT and found that the DHKT varies with household structure (number of employed householders). People travel over the network present in a study area. The DHKT does not take into account the underlying friction of travelling over the network. As a result, network based distance has been adopted to measure the size of activity spaces. In their study, Wyllie and Smith (1996) have reported that the mean travel distance for discretionary activities is higher for female than male extroverts. Kawase (1999) has used mean travel distance expressed in minute to measure the size of commuting activity spaces in a suburb of Tokyo. He has found that the size of activity spaces is shorter for married women than married men and the size is relatively stable for the married women who are professionals than employee. Schönfelder and Axhausen (2003) have used the distances between activities (shortest path distance) as an indicator to the size of activity spaces to measure social exclusion. Shortest path distance method also has been referred as minimum spanning tree in the literature (Miller, 2006). Although travel distance (both route length and travel time) could be a good proxy as an indicator to the size of activity spaces, it does not reveal areal extent of the activity spaces. The area based indicators have provided opportunity to explore coverage, dispersion, and orientation of activity spaces (Buliung and Kanaroglou, 2006a).

Three dominant uses of area based measures found in the literature are: standard distance circle (SDC), ellipse, and minimum convex polygon (MCP). SDC is an extension of standard distance (SD) measure. The SD of activity spaces is the standard deviation of distances among activity points from their mean centre (Bachi, 1963). It provides insight into the spatial spread or dispersion of the activity points about the mean centre. A large value for the SD implies a disperse pattern. As can be seen in Schönfelder (2001), the degree of dispersion varies quite significantly among different groups (e.g. sex, occupation, car ownership). Buliung and Kanaroglou (2006b) have used the SD of the activity locations as radius of a circle and generated the SDC from the mean centre. Using the SDC measure, they have shown that the activity spaces for a sub-urban household is more disperse than an urban household. Similar method has been adopted by McCray and Brais (2007) and found that women with car ownership have greater size of activity spaces than non car users. They have also reported that home location from transit route influences the size of activity spaces for the non-car user. Although the SDC might suggest a dispersed or clustered pattern of activity spaces with areal extent, it cannot be used to investigate orientation or shape of the activity spaces (Buliung and Kanaroglou, 2006a). Buliung and Remmel (2008) have mentioned that individual activity spaces are likely to possess these properties due to heterogeneity in the spatial and spatio-temoparal distribution of activity destinations, and the spatial structure of road networks.

Ellipse provides a unique approach to getting around the problem. It graphically represents the shape and direction of observed activity spaces on the one hand. On the other hand, the area of the ellipse represents the spatial extent of the activity spaces (Newsome et al., 1998). One of the ellipse based measures is confidence ellipse or standard deviation ellipse (SDE). The SDE is analogous to the SD of univariate distribution (Schönfelder and Axhausen, 2003). Ellipse has been used to compare the dispersion between travellers as well as to measure the temporal variation of intrapersonal travel (Schönfelder and Axhausen, 2003; Buliung et al., 2008). Since the SDE is generated about a single point (the mean centre or any exogenously defined centre of gravity), it is evident that much of the area inside an ellipse remains blank (Buliung and Remmel, 2008). Schönfelder and Axhausen (2003) have overcome the problem by creating two ellipses centred on two pegs (e.g. home and office). However, the elliptical shape has been lost after merging the two ellipses. Newsome et al. (1998) have proposed a practical approach to overcome the problem. In their work, Newsome et al. (1998) have blended the concept of activity spaces and the PPA construct. Instead of drawing two ellipses, they have drawn a single ellipse using the distance of the furthest activity location among the discretionary activities from the foci of the ellipse. The foci represent the pegs (e.g. home and office). Therefore, all other activities remain within the ellipse. The ellipse then represents an inner limit of the PPA over which an individual is able to engage in activities. They have quantified their ellipse construct in two ways. Firstly, the ratio of the minor to major axis indicates the fullness of the ellipse representing the relative extent to which the traveller is willing, able, or required to deviate from the main travel route. Secondly, the area of the ellipse represents the size of the activity spaces. They have combined the outcome of these measures with travellers' characteristics and found potentially useful in understanding travel behaviour.

Another area based measure, the MCP, has recently been introduced in the travel behaviour research (Buliung and Kanaroglou, 2006a; 2006b). It was first introduced to the ecology literature in the late 1940s as an approach to measure animal home-range (Mohr, 1947). With respect to human travel behaviour, the MCP is the smallest convex polygon containing all activity locations of an individual (Buliung et al., 2008). It provides a measure of the area or maximal geographical extent of the activity space on the one hand. Visually, the MCP also provides a generalised depiction of the shape of the activity spaces on the other hand. Buliung et al. (2008) have mentioned that the MCP is a supplementary measure of traditional areal based measures (e.g. ellipses). They have used the measure to explore weekday-to-weekend and day-to-day variation of travel behaviour. Buliung and Kanaroglou (2006b) have demonstrated the size of activity spaces varies between CBD-based households and sub-urban households using the MCP measure.

Although the area based measures are insightful, Buliung et al. (2008) have indicated several limitations too. First, the presence of outliers (distant activities) can give the impression that a very large area is being covered for daily activities when, in fact, the majority of locations may be clustered within a particular sub-area. Although the outliers have been excluded to measure home range for animal population, Buliung and Remmel (2008) have indicated that the exclusion within the activity-travel context requires refinement due to the presence of lengthy commutes. Second, the area based measures include areas that are either never used by individuals due to lack of information or the presence of physical barriers. Third, these measures cannot be applied when activity locations are spatially collinear, a situation that can arise when respondents live, work and play along a transport corridor. A possible way forward of getting around these limitations is the introduction of density based measure. The idea is that the activity spaces have a density at any location in the study area, not just at locations where there is an activity. The density is estimated by counting the number of events in a region, or *kernel*, centred at the location where the density estimate is required. The simplest approach is to use a circle as *kernel*. However, the choice of *kernel bandwidth* (radius of the circle) strongly affects the results. In practice, the problem is often reduced by focusing on *kernel bandwidths* that have some meaning in the context of the study (O'Sullivan and Unwin, 2003). Worton (1989) first applied kernel methods to estimate utilisation distribution (UD) to measure the size of home range. The kernel home range estimate is generally reported as the minimum area that includes a fixed percentage of the estimated UD volume (Marzluff et al., 2001). Relating to human spatial behaviour, Schönfelder and Axhausen (2003) have used this measure and calculated the area of activity spaces by counting the number of cells with positive density. They have related the measured size of activity space with socio-economic data to explore social exclusion.

3. Discussion

Based on the empirical evidences reviewed in the previous section, it is clear that the outcome measure corresponds well to the processes involved with social exclusion. Size of activity spaces is constrained by the processes. It varies depending on an individual's gender (Wyllie and Smith, 1996; Kawase, 1999; Kwan, 1999), employment (Kawase, 1999; Schönfelder, 2001; Buliung and Kanaroglou, 2006b), car ownership (Schönfelder, 2001), ethnicity (Goldhaber and Schnell, 2007), home location (McCray and Brais, 2007), poverty and neighbourhood environment (Rollinson, 1991), and time (Schönfelder and Axhausen, 2003; Buliung et al., 2008). From this perspective, the size of activity spaces could be a good indicator to identify the socially excluded.

Although the size of activity spaces has been used as an indicator of an individual's potential accessibility (space-time accessibility) for a long time, it is relatively a recent development to identify the person at risk of transport related social exclusion. The indicator should be carefully used in the field of social exclusion for several reasons. Firstly, PPA determines the size of an individual's potential activity spaces by measuring the size of the opportunities present inside an individual's DPPA. Existence of an opportunity within a DPPA does not necessarily mean that an individual has participated in this activity. Secondly, the DPPA is the aggregation of all the PPAs in a single day. Using the empirical evidence from Buliung et al. (2008) and Schönfelder and Axhausen (2003), it can be said that an individual will travel and participate in more discretionary activities throughout a week. Thus, the DPPA underestimates the size an individual's potential activity spaces and requires aggregation of several days PPA. Thirdly, within the network present in a DPPA, not every segment of the network can be potentially accessible for an individual. For instance, only the road segments served by public transport would be an indicator of the size of a person's DPPA who does not own a car; and public transport is the only mode of travel. Similarly, not all the opportunities (e.g. buildings) exist within a person's DPPA are accessible for him.

The above weaknesses of DPPA have been overcome by the concept of actual activity spaces. White (1985) has denoted the observed activity spaces as a frame of reference within which attitude, intentions and preferences are shaped and beyond which awareness of opportunities is constrained. However, among the two levels of actual activity spaces, macro-level activity spaces would not be practical to use because it is an aggregated measure. Therefore, the concept of micro-level actual activity spaces remains the only option to operationalise in the field of social exclusion. It is clear from Section 2.2 that there exists no standard for depicting the size of actual activity spaces. The indicators are undoubtedly multi dimensional starting from count based to density based. Area based measures that have been operationalised to the study of actual activity spaces are still geometric in nature and can be improved upon. Researchers who are involved to measure the potential size of activity spaces have abandoned the geometric measure and adopted network based measure (see, Miller, 1991; Kwan and Weber, 2008). Shortest path distance which has been used to measure the size of both the actual and the potential activity spaces is just an approximation. Schönfelder and Axhausen (2003) have indicated that in reality a traveller may leave the idea of travelling using the shortest path if s/he feels other constraints (e.g. congestion).

None of the single indicator can reveal the exclusionary aspects clearly in isolation. The following scenarios can aid in understanding the importance of each indicator to measure social exclusion. Scenario 1: an individual lives in a city centre who has participated in many activities located close by. Naturally, the areal extent of his/her activity spaces would be smaller and only an area based indicator may mislead to the measure of social exclusion. On the other hand, smaller size (area) of activity spaces may be the result of fewer numbers of activity participation. Thus a count based indicator would complement the area based measure. Scenario 2: a person has visited several dispersedly located shopping centres in a city. Here, both the count and the area based measure will indicate a larger size of activity space although the person has participated in only one type of activity. Scenario 3: two persons living in the same area who have visited the same places. They would have same size of activity spaces both in terms of area, count, and type based indicators. But if one person spends more time on those activities than the other, his/her chance of being socially excluded is less. The same would have happened if one person visits more frequently (maintain regular contact) than the others. Scenario 4: a person travels long distances daily to participate in fewer number of activity locations for a short time. Although several indicators (count, duration, type) indicate a smaller size of activity spaces, the person cannot be considered as transport related socially excluded because of his ability to travel longer distances. Moreover, none of the indicators reveals how big an individual's activity spaces are in relation to the micro-level (e.g. city) under consideration.

Based on this discussion, it can be said that the indicators of the size of activity space in isolation does not clearly indicate whether a person is excluded because all the indicators have impact to the measure of social exclusion. Therefore, a unique approach of measuring the size of activity spaces deemed is necessary.

4. An index to the measure of social exclusion

From the above discussion, it is clear now that analysis of participation in different activities for a single day is not good enough to conclude whether an individual is excluded or not and requires the analysis for multiday. Besides, it is important to include the following aspects to determine the size of activity spaces: type of participation, number of participation, frequency of participation, temporal extent of participation (duration), spatial extent of participation (area of activity spaces), and distance travelled. Based on these issues, the following indices (Equation 1 – Equation 7) have been developed to measure each dimension of participation.

$$\text{Participation type index (PTI)} = \frac{\text{Number of activity classes participated}}{\text{Total number of classified activities}} \quad \text{.....Equation 1}$$

$$\text{Participation count index (PCI)} = \frac{\text{Number of uniquely visited locations}}{\text{Total number of locations present within the city}} \quad \text{.....Equation 2}$$

$$\text{Participation extent index (PEI)} = \frac{\text{Area of activity spaces}}{\text{Study area}} \quad \text{.....Equation 3}$$

$$\text{Participation length index (PLI)} = \frac{\text{Total distance travelled in unique network}}{\text{Total length of network present in the study area}} \quad \text{.....Equation 4}$$

$$\text{Participation duration index (PDI)} = \frac{\text{Total time spent in activities}}{\text{Total time available}} \quad \text{.....Equation 5}$$

$$\text{Participation (activity) frequency index (PAFI)} = \frac{\text{Total number of visited activities}}{\text{Number of uniquely visited locations}} \quad \text{.....Equation 6}$$

$$\text{Participation (travel) frequency index (PTFI)} = \frac{\text{Total distance travelled}}{\text{Total distance travelled in unique network}} \quad \text{.....Equation 7}$$

The indices are prepared separately to examine correlation between each index and the socio-economic variables. Although separate indices are helpful in understanding a particular aspect of a phenomenon, several authors have highlighted the need for a composite index for its ability to summarise, focus and condense the enormous complexity of the phenomena to a manageable amount of meaningful information (Stapleton and Garrod, 2008; Singh et al., 2009). Several important and complex research issues need to be resolved to form a composite participation index (PI). These are: 1) measuring unit of the indices; 2) multivariate analysis to explore the underlying structure of the indices; 3) scaling of the indices; 4) weighting and aggregation of the indices; and 5) relativity of the measure (EC, 2008; Singh et al., 2009). Reflecting to the first research issue, Singh et al. (2009) have mentioned that a composite index is advantageous when sub-indices have no common meaningful unit. The prepared indices are ratios of any particular dimension of participation; and therefore have no unit and can be applied directly. EC (2008) has highlighted to carefully analyse the underlying nature of the indices to avoid the notion of 'indicator rich but information poor'. Different statistical multivariate techniques (e.g. principal component analysis, factor analysis) can be used to explore whether the indices are statistically well-balanced in the composite index. This will also help to choose a relevant weighting method in later stage. EC (2008) has also indicated that if the indices are not well-balanced, a revision of the individual indices is necessary. This paper has not conducted the multivariate analysis yet due to lack of substantive empirical data. Relating to the third issue, the scores from Equation 1 to Equation 5 are already scaled on the one hand. The scale ranges from 0 to 1. On the other hand, the scores of Equation 6 and Equation 7 would be any value ranging from 1 to any number and requires scaling. Although different scaling methods exist, following linear scaling transformation method proposed by Pyle (1999) has been adopted to fit with the above scale range (Equation 8).

$$\text{Scaled score} = \frac{\text{Observed score - 1}}{\text{Maximum score - 1}} \quad \text{.....Equation 8}$$

Weights play a significant role on the overall composite index. A number of weighting methods and their suitable aggregation method can be found in EC (2008) and Singh et al. (2009). Some of them are based on subjective judgement of the experts e.g. analytic hierarchy process (AHP), budget allocation process (BAP) whereas others are based on objective judgement derived from statistical techniques such as principle component analysis (PCA), factor analysis (FA). However, most commonly used weighting method for composite index is equal weighting and can be applied to calculate the PI as well (EC, 2008). Assigning equal weight to the indices may introduce double counting if the indices are highly correlated and therefore requires attention before its application. The multivariate analysis among the indices in the earlier stage thus reduces the chance of double counting. This paper intends to adopt linear aggregation method as suggested by EC (2008) and Singh et al. (2009) because the indices have no unit on the one hand. On the other hand, the composite index can then be used relatively because the individual indices measure participation in each dimension relatively. For instance, it is possible to say that an individual with a score 0.50 in the PDI has spent time twice for activity participation than an individual with a score of 0.25 though the scores may be the result of completely different type of activity participation. From the above analysis, this paper has proposed Equation 9 to measure the composite PI:

Participation Index (PI) = w(PTI + PCI + PEI + PLI + PDI + Scaled PAFI + Scaled PTFI) …………………Equation 9

Where, w represents equal weight. However, the number of individual indices to be finally considered depends on the outcome of the multivariate analysis of the indices upon availability of empirical data. Caution must be taken for the analysis of participation for multiday using the indices to maintain relativity. For instance, in a week long participation, calculation of each day index and summing it for seven day may mislead the outcome. In case, an individual has visited one type of activity in different locations for seven days. His PTI for a day would be 0.1 if the total number of activity class is considered 10 and summing it for seven days would be 0.7. However, it should only be 0.1 because he has participated only one type of activities out of ten over a week. Therefore, aggregation of several days' activity at the first instance is important while each day activity should be traceable for the analysis of intrapersonal spatio-temporal variation of activity participation. The PI can also be linked with the individual's socio-economic variable to search for pattern. Again, average of the PCI, PEI, and PLI scores could be used to depict the size of an individual's activity spaces in terms of his/her study area.

To measure individual indices required detailed (ex-ante) disaggregate data. Detail travel and activity data together with socio-economic characteristics must be available to show the locations, movements and activities of individuals. If travel data is collected through a travel diary (TD) survey, it should include the following elements for each trip: left at (time), left from (address), to go to (address), got there at (time), trip purpose, transport mode, and route/roads travelled. Each trip is meant here as any purposeful stop during a journey. Besides, a list of purposes must explicitly be provided to the respondents to choose from. This list will subsequently be used for the analysis of PTI. This will, no doubt, produce enormous amount of data. Effective tools like GIS has been suggested as a possible way forward (Dykes, 1996; Gahegan, 2000). Figure 1 has been prepared as a framework to exhibit how GIS (*ArcGIS*) can be used to handle the complexity. The framework has been tested using a pilot TD survey data. Three tables have been prepared using the TD: *Personal* table*, Origin-Destination (OD)* table, and *Trip by Road* table. *Personal* table is attributed with socio-economic data (e.g. age, sex, income, car ownership) of the individuals. *OD* table represents an origin and a destination of each trip. It is also attributed with trip start time, end time, purpose and time spent at destination for each trip. *Trip by Road* table captures a unique *ID* (identity) for each segment of the network that each trip is comprised of. That means each record in the table represents *Trip ID* and *Road Id* with mode of travel of that particular segment. Two shape files have been collected from secondary sources. One is a point based addresses of activity locations (OD layer) and the other is a road network (road layer) covering the study area. All *tables* and *shape*s have been inserted into a *personal geodatabase*. *ArcGIS ModelBuilder* functionality has been used to process the data to derive individual indices.

Figure 1 schematically represents the processes and the outputs of the model. The framework is only showing two trips, two origins and two destinations. In actual model, the number was as many as the total number of trips undertaken by the individuals over the survey period. Although the framework is showing the three elements (origins, destination, and segments) together, they have been prepared in three separate models for easy processing. Finally, the outcomes (*all origins, all destinations,* and *all trip segments*) from each model have been brought to a final model for the analysis of individual travel behaviour.

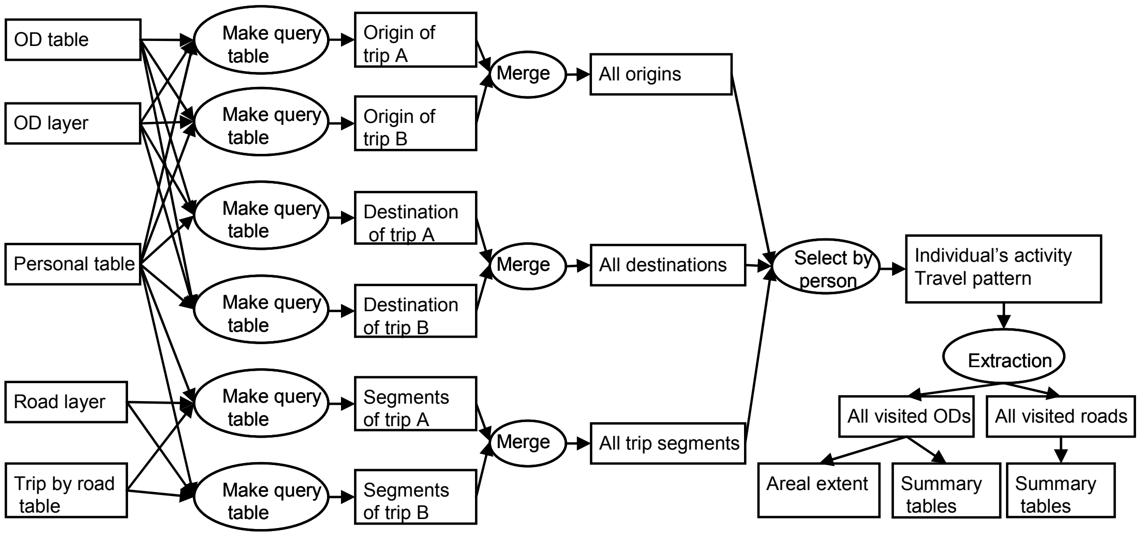

Figure 1: A framework to operationalise the Participation Index measure in ArcGIS

A methodological problem this paper has faced is how to visualize the individual travel behaviour in a two dimensional map. An individual can use one road segment, one origin and one destination several times for similar/variety of purposes (e.g. shopping, education) and using similar/different modes over the period. To visualize all these patterns requires the presence of that particular *object* several times in a *shape file*. But the *topology* rule of a *shape file* does not allow duplicate *objects*. One way of getting around this problem is considering time as the third dimension. Kwan (2000) has mentioned that an interpretation of the 3D patterns are highly complex on the one hand. On the other hand, there are limitations to producing clear illustrations of those 3Ds using 2D graphics in a paper. Therefore, 3D visualization option has been abandoned. This paper has found the other way of getting around the problem is to extract relevant *objects* (origin, destination and road segments) for a single trip at a time from the respective *shapes* using a *SQL query*. A single trip interacts with one origin, one destination and each segment for only once. That is why, it is mentioned earlier that every purposeful stop should be counted as a single trip. All extracted *objects* for each category have been merged to form *all origins*, *all destinations* and *all segments shapes*. The *Merge* functionality allows the presence of duplicate *objects* required for the visualization of trip sequencing. From the *merged shapes*, the visited *objects* (origins, destinations, and segments) for an individual have been extracted by query. These *objects* have been used to visualise individual travel behaviour. The *objects* together with their attached *attributes* have been summarised to measure the value of individual indices. Limited number of TD has been collected over the TD survey. Therefore, no empirical results have been provided in this paper.

5. Conclusion

Social exclusion can be measured in two ways: by using the indicators of its processes or its outcome. Participation has been found as the key outcome of social exclusion in the literature. Traditionally, accessibility has been used as an indicator of the outcome measure of transport related social exclusion. Since accessibility in its current operational form does not reflect an individual's participation in society, researchers have attempted to operationalise the activity spaces concept as an outcome measure of transport related social exclusion. However, there is no unique approach found in the literature to measure the size of activity spaces. Each dimension of the activity spaces measure represents one aspect of social exclusion. Therefore, it was necessary to unify the measure to identify socially excluded and a participation index (PI) has been developed. Operationalisation of the PI has been found a daunting job and requires highly disaggregated activity-travel data of individuals. A framework to operationalise the PI in *ArcGIS* has been found indispensible to handle the complexity of the data. The framework would be helpful to calculate the individual indices required for the composite PI measure. The PI can be used to identify the excluded but its empirical evidence is an utmost need.

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